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The influence of thermophoretic particle deposition on fully developed MHD mixed convective flow in a vertical channel with thermal-diffusion and diffusion-thermo effects

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Abstract The present paper deals with the influence of thermophoretic particle deposition on the MHD mixed convective heat and mass transfer flow in a vertical channel in the presence of radiative heat flux with thermal-diffusion and diffusion-thermo effects. The resulting nonlinear coupled equations are solved under appropriate boundary conditions using the homotopy analysis method. The influence of involved parameters on heat and mass transfer characteristics of the fluid flow is presented graphically. It is noted that fluid velocity is an increasing function of radiation parameter, Dufour number, Buoyancy ratio parameter and mixed convection parameter whereas the magnetic parameter, thermophoresis constant, Soret number and Schimidt number lead to suppress the velocity. The fluid temperature increases with increasing radiation parameter and Dufour number. The convergence of homotopy analysis method (HAM) solutions is discussed and a good agreement is found between the analytical and the numerical solution.

1. Introduction

Mixed convection flow in a vertical channel has been the subject of many investigations due to its important applications in industrial and engineering processes such as cooling of electronic equipment, heat exchangers, chemical processing equipments and others. Also, mixed convection flow in a vertical

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Nomenclature

B	buoyancy ratio parameter
B_0	transverse magnetic field
C	concentration of the fluid
C_1, C_2	wall concentrations
c_p	specific heat at constant pressure
c_s	concentration susceptibility
D_u	Dufour number
D_m	coefficient of mass diffusivity
g	Gravitational force
G_r	Grashof number
G_R	mixed convection parameter
K	thermal conductivity
k	non-dimensional thermophoretic coefficient which depends on Knudsen number
k_T	thermal diffusion ratio
L	width of the channel
M	magnetic parameter
N	radiation parameter
N_t	non-dimensional parameter
Nu	Nusselt number
P	pressure
P_r	Prandtl number
q	radiative heat flux
Re	Reynolds number
S_c	Schmidt number
Sh	Sherwood number
S_r	Soret number
T	temperature of the fluid
T_1, T_2	wall temperatures
$\overline{T}$	mean value of T_1 and T_2
u	fluid velocity
U_0	entrance velocity
v	thermophoretic deposition velocity
V_T	non-dimensional thermophoretic velocity

Greek symbols

θ	non-dimensional fluid temperature
ϕ	nondimensional fluid concentration
β_c	coefficient of volume expansion
β_T	coefficient of thermal expansion
μ	dynamic viscosity
σ	electrical conductivity
ρ	fluid density
ν	kinematic viscosity
α	non-dimensional pressure gradient
α_1^2	mean absorption coefficient
τ	skin friction

channel in the presence of a transverse magnetic field is of special technical significance because of its industrial applications such as geothermal reservoirs, cooling of nuclear reactors, petroleum reservoirs and so on. This type of problem arises in electronic packages, microelectronic devices during their operations also. Excellent reviews of the mixed convection hydromagnetic flows in vertical channel have been presented by many authors [1–5]. Later, Srinivas and Muthuraj [6] have examined the problem of MHD flow in a vertical wavy porous space in the presence of a temperature-dependent heat source with slip-flow boundary condition. They have also examined the effects of chemical reaction and space porosity on MHD mixed convective peristaltic flow in a vertical asymmetric channel [7]. Fully developed mixed convection flow in a vertical channel filled with nanofluids was discussed analytically by Xu and Pop [8]. Rashidi et al. [9] have analyzed the effects of partial slip and thermal-diffusion and diffusion-thermo on Steady MHD Convective Flow due to a Rotating Disk.

Thermophoresis is a phenomenon observed in mixtures of mobile particles where the different particle types exhibit different responses to the force of a temperature gradient. The term thermophoresis most often applies to aerosol mixtures, but it may commonly refer to the phenomenon in all phases of matter. This thermophoresis process has gained importance for many engineering applications and is utilized in air-cleaning devices to remove submicron- and micron-sized particles from gas streams ([10–21]). In view of these applications, a theoretical analysis for thermophoretic transport of small particles through a fully developed laminar, mixed convection flow in a parallel vertical channel was presented by Grosan et al. (see Ref. [16] and several references therein). Later, thermophoretic transport in the steady fully developed mixed convection flow in a parallel-plate vertical channel with differentially heated isothermal walls was studied by Magyari [17]. Mahdy and Hady [18] have analyzed the effects of thermophoretic particle deposition on the free convective flow over a vertical flat plate embedded in a non-Newtonian fluid-saturated porous medium in the presence of a magnetic field. The effect of surface mass transfer on MHD mixed convection flow past a heated vertical flat permeable surface in the presence of thermophoresis, radiative heat flux and heat source/sink using similarity transformation was studied by Singh et al. [19]. Free convection thermophoretic hydromagnetic flow over a radiate isothermal inclined plate with heat source/sink effect using shooting method were presented by Noor et al. [20]. More recently, Guha and Samanta [21] have investigated the effects of thermophoresis and transverse magnetic field on aerosol particle transport and deposition onto a horizontal plate in the presence of a natural convective flow. To the best of our knowledge, no attempt has been made to analyze the influences of thermophoresis deposition, thermal-diffusion and diffusion-thermo on hydromagnetic flow in a vertical channel with asymmetric wall temperatures. Motivated by previous studies, a mathematical model is to be present to understand the combined effects of thermophoresis deposition, thermal-diffusion and diffusion-thermo on MHD flow in a vertical channel with heat and mass transfer. Such problems are important in flow analysis for the understanding of flow, heat and mass transfer characteristics. Analytic solutions for the velocity, heat and mass transfer components are obtained using a powerful, easy to use technique, namely the homotopy analysis method (HAM). It is worth mentioning that the HAM is a promising tool for solving non-linear problems ([22–35]). Heat and mass transfer characteristics of the fluid flow for